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Durability of Subslab Depressurization Radon Mitigation System Performance

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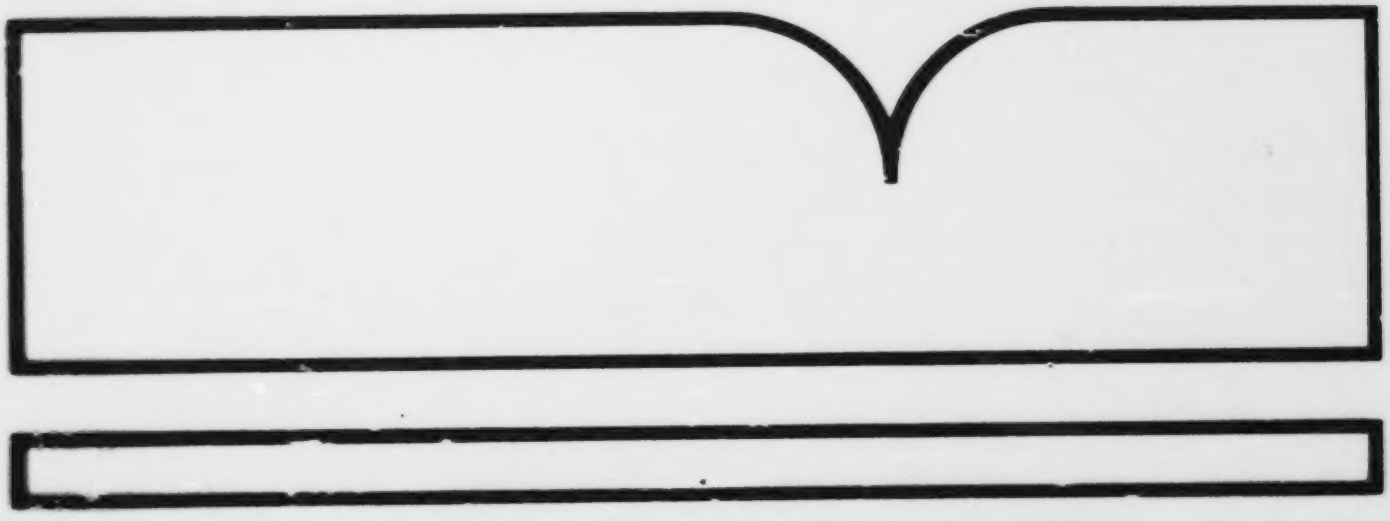

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16. ABSTRACT The paper gives results of a review of the quarterly performance of subslab depressurization (SSD) radon mitigation systems in eight houses in the New Jersey (NJ) Piedmont study and houses in which the NJ Department of Environmental Protection measurements have indicated operation at above the U.S. EPA guideline of 4 pCi/L. Quarterly radon levels, mitigation system noise levels and flow rates, exhaust radon level, moisture problems, and other pertinent operating parameters are evaluated. Homeowner influence on the operation of the mitigation systems has been documented and was shown to be the major cause of above-guideline levels of radon in mitigated houses.

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DURABILITY OF SUBSLAB DEPRESSURIZATION RADON MITIGATION SYSTEM PERFORMANCE

EPA/600/D-90/109

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ABSTRACT

Questions have arisen as to how well subslab depressurization (SSD) radon mitigation systems perform over the longer term. Are the U.S. EPA guideline levels of 4 pCi/L being exceeded months or years after the building has been mitigated? With these questions in mind, we have been reviewing the quarterly performance of radon mitigation systems in eight of the houses in the New Jersey (NJ) Piedmont Study and houses in which the NJ Department of Environmental Protection measurements have indicated operation above the U.S. EPA guideline. Quarterly radon levels, mitigation system noise levels and flow rates, exhaust radon level, moisture problems, and other pertinent operating parameters are evaluated. Homeowner influence on the operation of the mitigation systems has been documented and was shown to be the major cause of above-guideline levels of radon in mitigated houses.

INTRODUCTION

During the winter of 1986-87, 12 houses in New Jersey were mitigated by professional mitigators, to the specifications of researchers, as part of the Piedmont Study (1). Subslab and/or blockwall depressurization was the mitigation system of choice. The two remaining houses of the study were mitigated during the following year of the study. The radon levels in the basements and crawlspaces were reduced from as high as 200 pCi/L to 4 pCi/L or less.

Questions about the durability of the mitigation system operation and the stability of the radon levels had not been addressed quantitatively up to this point (2,3). The suction fans, sealing materials, and other components of the mitigation systems had come from other industries and had not been tested in this operating environment. Moisture from the soil and particles of soil or other contaminants may cause premature fan motor or bearing failure. Drying of the subslab area had been noticed during the Piedmont Study, and concerns as to whether this drying may affect the substructure in a negative way (such as slab or wall cracking) had to be answered.

This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.

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METHODOLOGY

Our approach to evaluation of durability is based on our experience as well as the experiences of others in the research community; e.g., New York State Energy Research and Development Authority (4), Lawrence Berkeley Laboratory (5), and Swedish studies (6).

An occupant questionnaire was designed to provide answers about their perception of the functioning of the mitigation system (7). Questions were asked (and replies recorded) relating to noise, moisture in the house or associated with the mitigation systems, whether the system has been operating steadily and, if not, why it was turned off, and if there were any events in or near the house, such as construction, that would have influenced the operation of the mitigation system. Questions the homeowner asked about the mitigation systems were also recorded.

A diagnostics protocol was developed to address many of the areas of concern. The protocol includes visual inspection and measurement of the extent of cracking of the slab(s) or walls of the substructure, visual inspection of the quality of the sealed joints or cracks, and visual inspection for any symptoms of water or moisture problems that may have been a result of the mitigation. The mitigation system was checked for noise or vibrations that may indicate fan motor, bearing, or mounting hardware failure. Airflow in the mitigation piping was measured in each branch and in the main exhaust pipe. Pressure differentials between the basement and subslab, and the basement and mitigation piping, were measured. Radon gas grab samples were taken from the mitigation exhaust, and alpha track detectors were installed in the basement/crawlspace and living spaces of these houses.

These procedures were performed on an approximately quarterly schedule and the data recorded. If any changes from the previous data were noted, a determination as to the cause was made immediately. In the case of major changes in radon levels, the results would not, however, be known until they were received from the testing laboratory.

PIEDMONT STUDY RESULTS

Occupant Effects

Immediately evident is that, while the majority of houses show fairly constant radon levels (Table 1) over time, two houses (3 and 5) show major variations in radon levels. The variations indicate a return to near pre-mitigation levels of radon (Figure 1).

Checking the responses to the occupant questionnaire, the occupant of House 5 had turned the subslab depressurization (SSD) system off because of interference on the AM band of his radio. He also thought that running the SSD system in the summer was wasting energy and that turning the SSD system off and opening the basement windows would keep their radon levels below the guideline.

The occupant of House 3 indicated that the SSD system had been off for only about 3 hours during a power outage but otherwise had been operating continuously since it was installed. After we informed the homeowner that the radon levels had returned to the pre-mitigation levels, we were told the system had been turned off during a dinner party because it was making enough noise to make conversation difficult. The dining room was located next to the garage which housed the mitigation fan. Our investigation determined that the noise was a result of the fan housing pressing tightly against the second floor joist system which was acting as a sounding board and amplifying the fan vibrations. Modification of the fan mounting system eliminated the problem. Similar vibrational noise complaints have been found in one of our research houses and one of the New Jersey Department of Environmental Protection (NJDEP) houses. As a result, the SSD systems had been turned off in each of these houses for varying lengths of time.

Seasonal Effects

Table 1 lists the radon concentrations in the eight Piedmont Study houses over a 20 month period. If we disregard the data from Houses 3 and 5 where the occupants had turned the systems off, we note that the radon levels have not changed drastically in any of these houses. The radon levels in House 6 decreased from an average of 5 pCi/L to 2.5 pCi/L after the first 4-month reading, while the radon levels in Houses 2, 4, 7, and 10 vary only slightly during the different seasons. These variations are within the error band of the alpha track measurement technique used to determine the integrated indoor radon levels. The radon levels in House 8 peak at or above the U.S. EPA guideline during the winter measurement periods, but on an annual average meet the guideline.

Radon Levels in the Mitigation System Exhaust

The radon concentrations and flows were measured in the SSD mitigation system exhaust during each quarterly visit, which can be used to calculate the total flow of radon gas from the mitigation system (8). In the absence of a mitigation system, the "natural flow" rate of radon through the house to the ambient air would be the airflow rate (i.e., the average air infiltration rate, AI_{avg}) of the house times the indoor radon concentration. The ratio of these two flow rates could provide a preliminary measure of the additional subsoil radon drawn out of the soil and released to the ambient air as a result of installing the SSD mitigation system.

Results of this type of simple analysis are shown in Table 2. The ratio of the radon gas being exhausted from each house by the mitigation system to the natural radon flow through the house in the unmitigated state varies from 1 to 9 for these Piedmont Study houses. The subslab and surrounding soil conditions play an important role in determining the amount of radon entry into the house or available to the mitigation system. For instance, House 4 is built on low porosity soil, wet clay, and has a natural radon flow rate comparable to the other houses, $7.5 \pm 3 \times 10^6$ pCi/h, except for House 3. House 3 is built on high porosity soil (i.e., stone floor roughly 0.3 cm diameter and has good gravel bed beneath the slab) and a natural flow rate of 35×10^6 pCi/h. Once the mitigation system is turned on, the ability of the system to communicate with the surrounding soil is demonstrated. The quantity of radon being exhausted from the mitigation system in House 4 is the same as the natural flow through the house. In other houses, such as 5 and 7, the "mining" of radon gas is demonstrated by the ratio of mitigation exhaust flow to natural flow, ratios of 9 and 8 respectively. Both of these houses are built on soils of a clay/shale mixture.

Substructure Changes

Only House 3 showed any evidence of cracking of the slab or basement walls. Two cracks appeared in the basement slab extending approximately 1.8 m from the perimeter towards the center of the slab. House 3 is the newest (5 years) of the houses studied, and these cracks may be from the normal settling of the substructure.

An observation of conditions beneath the slab was that the soil was noticeably drier since these SSD systems have been installed. Several homeowners stated that the need for dehumidification in the basement was eliminated in their houses. No quantitative measurements of relative humidity have been made.

CONCLUSIONS AND RECOMMENDATIONS

Within the scope of this paper, we have presented some of the results of the durability study of the performance of SSD systems installed in the NJ Piedmont study houses.

Other mitigated houses in the central NJ area were also tested and these data, along with durability data from Southern Research Institute (Florida houses) and Oak Ridge National Laboratory (Tennessee and Alabama houses), were analyzed.

This limited set of data seems to indicate several important factors. Homeowner interaction with their mitigation system can be a major determining factor as to whether the EPA guidelines are achieved. Noise, whether electrical, vibrational, or aerodynamic, has been the primary reason that systems have been turned off in all of the areas of the country studied. Some systems in Florida are being turned off when the homeowners, typically retirees, leave on extended vacations.

Another finding is that fan or component failures seem to occur soon after installation. Otherwise, the systems operate well (at least up to the 3 years studied) and maintain the reduced radon levels throughout the year.

Our recommendations to the mitigators would be to use long-service-life components, such as heavy-duty capacitors, 25 year rated sealants, and quality speed controls. Fan selection should be appropriate for the installation, and post-installation diagnostics should be performed to ensure proper operation. Care must be taken during installation to avoid complaints by the occupant regarding noise. We have observed little or no degradation of performance over time of properly installed SSD systems.

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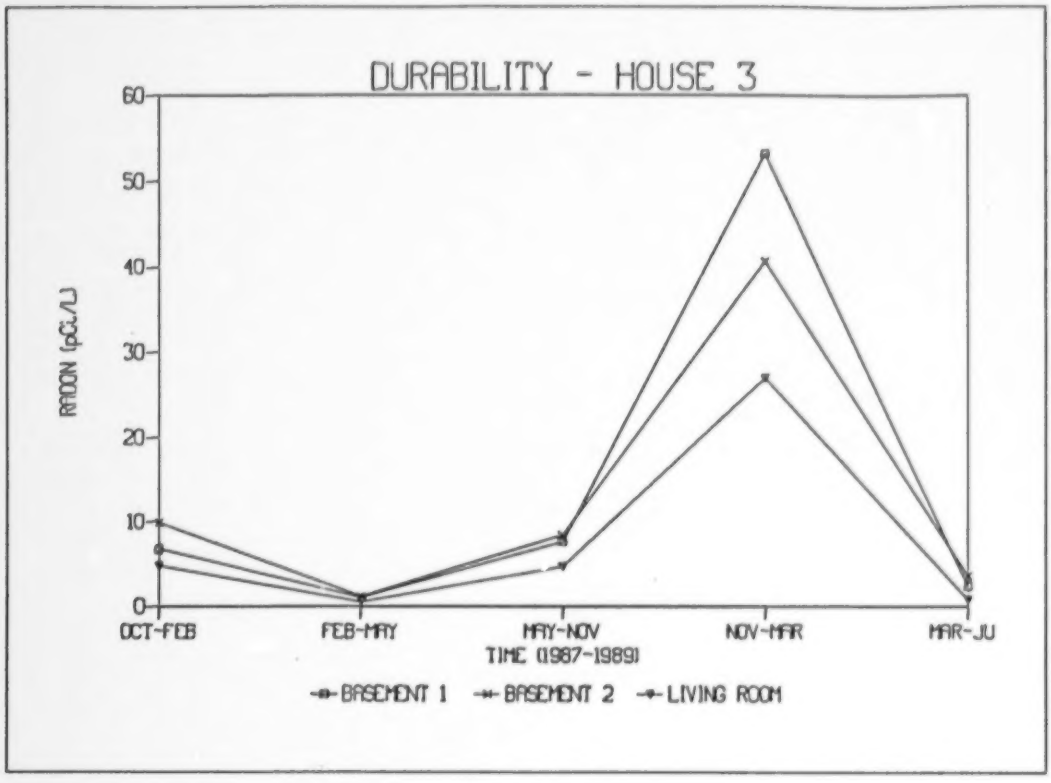
TABLE 1. RADON CONCENTRATIONS IN EIGHT HOUSES (pCi/L)

House No.	Location[1]	Oct.' 87 Feb. '88	Feb. '88 May '88	May '88 Nov. '88	Nov. '88 Mar. '89	Mar. '89 Jun. '89
2	Basement	2.1	1.9	1.4	1.8	1.3
	Basement	2.4	1.3	1.0	1.1	1.1
	Dining Room	---	---	0.6	1.5	0.4
3	Basement	6.8	1.1	7.6	53.2	2.5
	Basement	9.9	1.2	8.4	40.6	3.6
	Living Room	4.8	0.6	4.7	27.0	0.8
4	Basement	3.1	2.3	2.8	2.6	---
	Basement	3.0	2.6	2.8	---	---
	Living Room	2.8	3.1	2.7	1.8	1.0
	Breezeway	---	---	---	2.1	1.3
5	Basement	11.6	0.7	9.8	12.9	0.4
	Bedroom	8.4	0.8	6.0	12.4	0.6
6	Basement	4.8	1.9	1.7	2.7	3.1
	Basement	5.1	2.5	2.3	2.2	2.4
	Crawlspace	6.8	2.8	2.2	---	---
	Living Room	2.6	1.6	1.3	1.8	1.8
7	Basement	1.0	0.3	0.5	1.2	0.5
	Crawlspace	0.8	0.6	0.2	1.1	0.3
	Crawlspace	0.6	0.3	0.4	0.8	---
	Living Room	0.6	0.3	0.3	0.3	0.3
8	Basement	5.6	1.9	0.9	3.6	2.2
	Living Room	3.6	1.7	1.1	4.4	0.9
10	Basement	2.4	2.2	1.8	2.6	1.5
	Family Room	1.9	1.9	1.7	2.7	1.3

[1]. Multiple basement or crawlspace readings are from duplicate sensors placed 30 cm apart.

TABLE 2. COMPARISONS OF RADON QUANTITIES EXHAUSTED BY MITIGATION SYSTEMS AND BY NATURAL MEANS BASED ON FIVE HOUSES

House No.	Rn Level (pCi/L)		House Volume (m^3)		AI_{ave} (m^3/h)	Rn Level Exhaust (pCi/L)	Exhaust Flow (m^3/h)	Rn Quantity (pCi/h)		Ratio: Mitigation/Natural
	Basement	Upstairs	Basement	Upstairs				Exhaust	Natural	
2	22	15	219	296	398	154	102	15,731,000	6,974,000	2.26
3	170	70	224	469	338	946	76	73,167,000	34,585,000	2.12
4	29	56	211	499	283	44	246	10,902,000	10,478,000	1.04
5	60	35	371	398	135	435	132	57,767,000	6,353,000	9.09
7	33	18	199	392	203	504	76	38,687,000	4,680,000	8.27



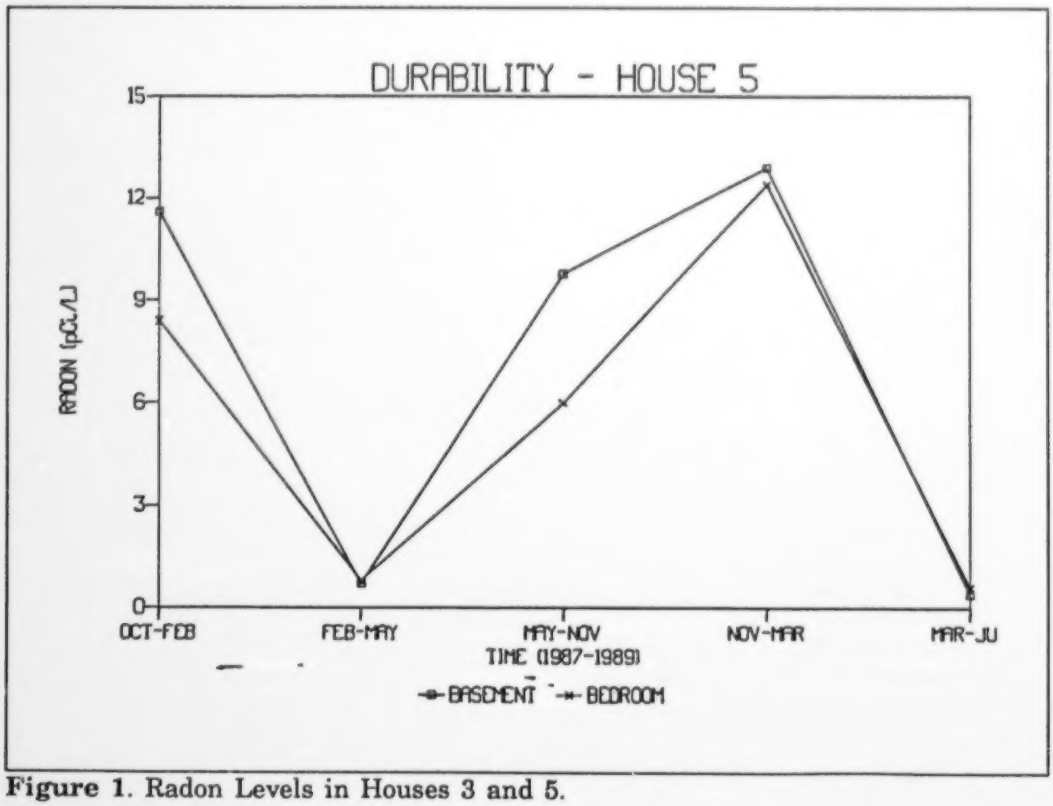


Figure 1. Radon Levels in Houses 3 and 5.